"Evaluation of Multilayer Cloud Detection using a MODIS CO_2-slicing algorithm with CALIPSO-CloudSat measurements."

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Outline

- Motivation
- Data and methodology
- Results
- Conclusions and discussion

Motivation

- Knowledge of cloud vertical structure is important for a variety of climate-related applications such as:
  - Understanding how clouds impact the Earth's radiation budget, and
  - Vertical distribution of latent heat and effects on global circulation and precipitation.
- One of the most important consequences of ignoring the multilayer clouds is the introduction of errors in deducing the radiative impact of clouds.
- Evaluate two different ways to estimate the presence of multilayered clouds based on the instrumentation (active-passive sensor).

Data and Methodology

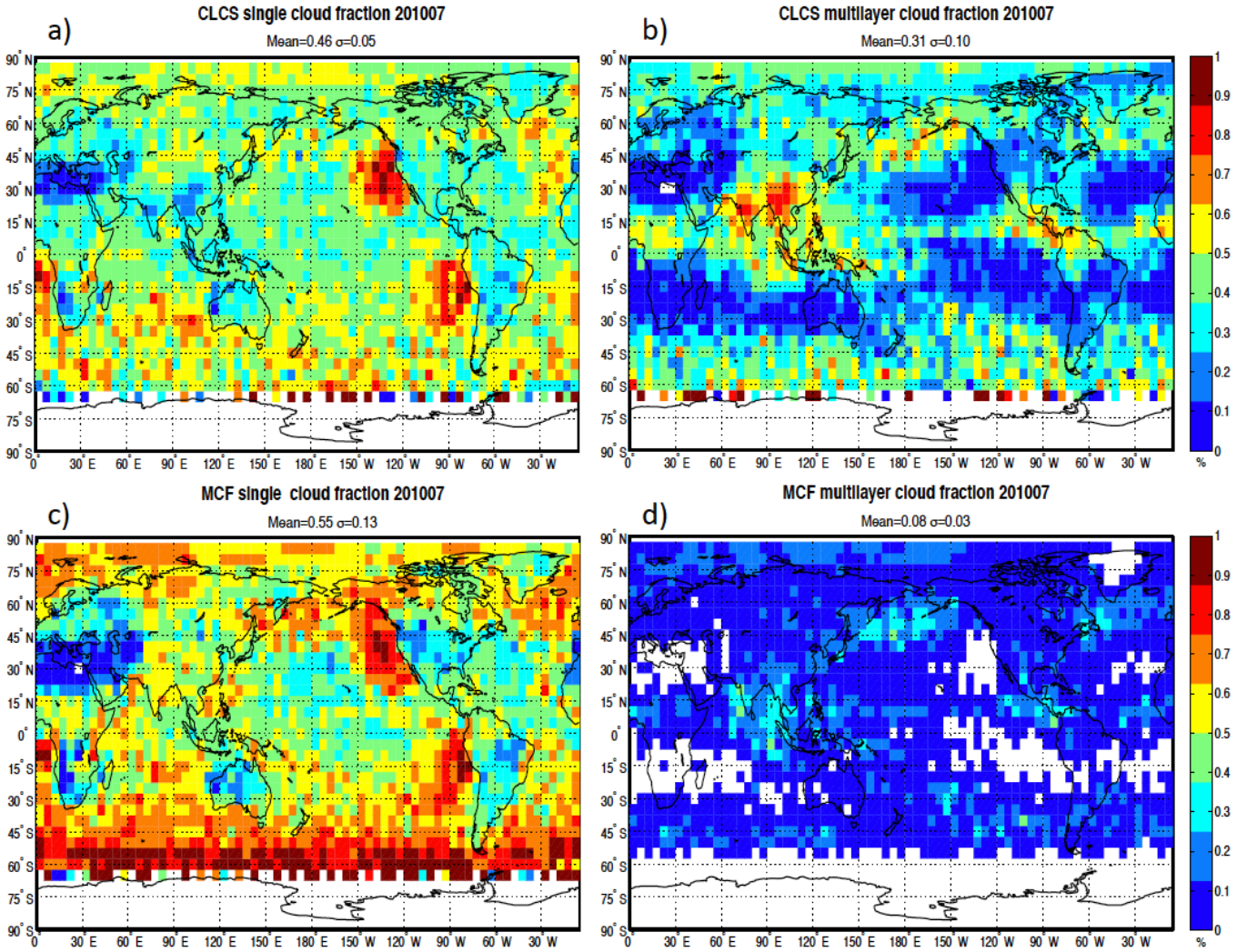
- CALIPSO-CloudSat (CLCS): Cloud and aerosol mask in CALIPSO-CloudSat-CERES-MODIS (CCCM) release C1.
  - Clouds grouped up to 16 groups by cloud coverage and up to 6 overlapped layers (*Kato et al 2010*).
  - All the multilayered cloud groups are averaged and weighed by CF.
- The Multilayer Cloud Footprint algorithm(*Fu-Lung et al. 2010*): CO_2 absorption technique to detect cases selected are only over CALIPSO and CloudSat ground track and cloud properties derived from the standard cloud algorithm.
- The MCF cases selected are only over CLCS ***ground track*** and cloud properties derived from the ***standard cloud algorithm***.
- The data for MCF (SSF Edition 4) in the CCCM Release C1 is currently only available for January, April, July and October 2010.

Set	Name	Cloud Algorithm	Cloud Mask	MODIS Pixel Coverage
1	Full	Standard	MODIS	Full CERES footprint
2	Track	Standard	MODIS	Along CALIPSO/CloudSat track only
3	Enhance Track	Enhanced	MODIS	Along CALIPSO/CloudSat track only
4	Enhance Full	Enhanced	MODIS	Full CERES footprint

Results

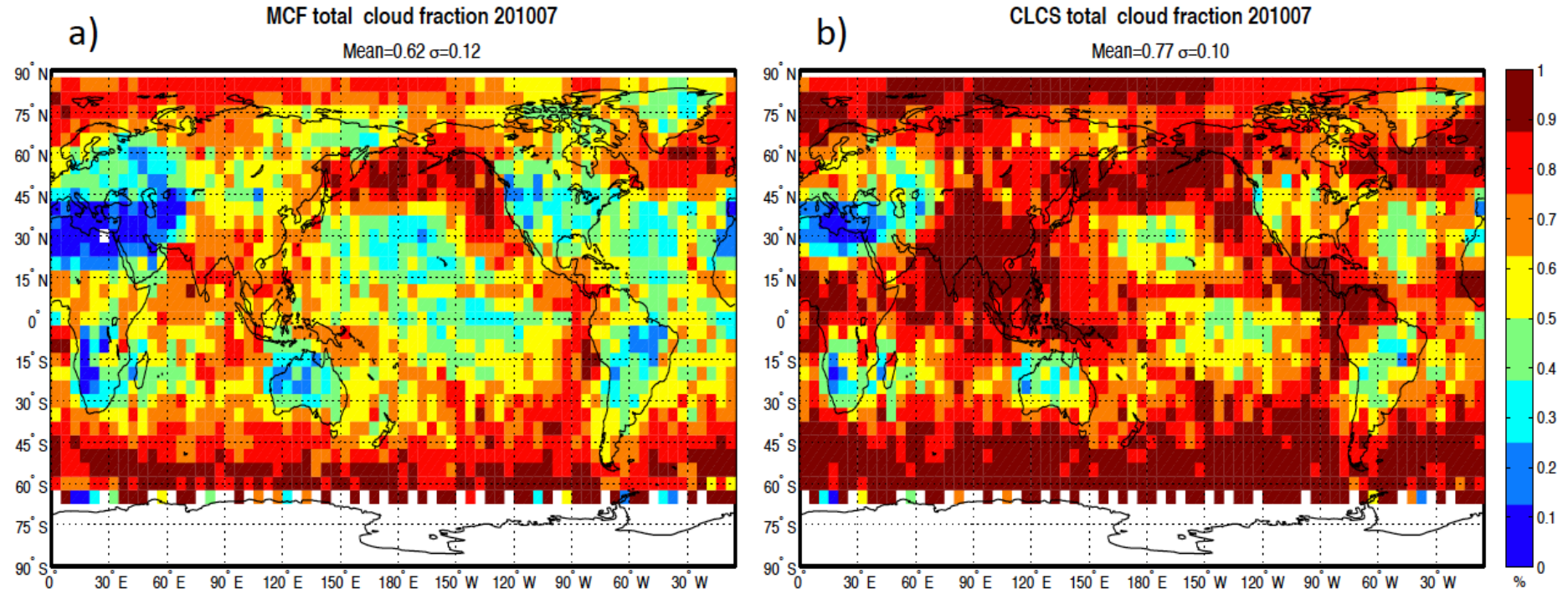
- How often does the MCF algorithm detect single or multilayer clouds?

Single and multilayer cloud fraction



		January	April	July	October
CLCS	Single	0.45±0.06	0.44±0.04	0.46±0.05	0.45±0.06
	Multilayer	0.28±0.08	0.32±0.08	0.31±0.10	0.30±0.08
MCF-SSF	Single	0.51±0.08	0.54±0.11	0.55±0.13	0.56±0.13
	Multilayer	0.10±0.05	0.07±0.04	0.08±0.03	0.08±0.03

Total cloud fraction



	January	April	July	October
CLCS	0.73±0.12	0.77±0.10	0.77±0.10	0.75±0.12
MCF-SSF	0.58±0.13	0.60±0.12	0.62±0.12	0.62±0.13

MCF algorithm underestimates the total cloud fraction in 15%

- Where does the MCF algorithm agree more with the CALIPSO-CloudSat mask?

Number of matched footprints by cloud overlap type

MCF / CLCS	January	April	July	October
SL / SL	219140	170390	182803	202912
SL / ML	76874	84200	89219	81492
SL / SLML	278510	328546	298101	315447
SL / clear	20783	16451	13172	18230
ML / SL	2070	738	944	973
ML / ML	3403	3076	3174	3002
ML / SLML	6307	3606	4597	4341
ML / clear	0	0	0	0
SLML / SL	7427	4773	5919	5515
SLML / ML	21710	24127	29749	22698
SLML / SLML	42892	40803	56489	43018
SLML / clear	2	13	118	17
Clear / SL	41394	57281	53887	50354
Clear / ML	1157	2494	7194	1064
Clear / SLML	13727	25324	21430	15020
Clear / Clear	66130	41847	36735	42195
Total	**801526**	**803669**	**803531**	**811242**

SL: single layer ML: multilayer SLML: single and multilayer

Frequency of cloud overlap occurrence over matched footprints

MCF / CLCS	January	April	July	October	Mean	
SL / SL	27.3	21.2	22.8	25.2	**24.1**	
SL / ML	9.6	10.5	11.1	10.1	**10.3**	
SL / SLML	34.8	40.5	37.1	39.1	**37.9**	**Total single**
SL / clear	2.6	2.1	1.6	2.3	**2.1**	**74.4**
ML / SL	0.3	0.1	0.1	0.1	**0.1**	
ML / ML	0.4	0.4	0.4	0.4	**0.4**	
ML / SLML	0.8	0.5	0.6	0.5	**0.6**	**Total multilayer**
ML / clear	0.0	0.0	0.0	0.0	**0.0**	**1.1**
SLML / SL	0.8	0.5	0.6	0.6	**0.6**	
SLML / ML	1.7	2.0	2.3	1.8	**2.0**	
SLML / SLML	3.6	3.4	4.7	3.7	**3.9**	**Total single-multilayer**
SLML / clear	0.0	0.0	0.0	0.0	**0.0**	**6.5**
Clear / SL	5.3	7.2	6.8	6.3	**6.4**	
Clear / ML	1.1	1.4	2.3	1.1	**1.5**	
Clear / SLML	3.5	4.8	5.0	3.5	**4.2**	**Total clear**
Clear / Clear	8.3	5.2	4.6	5.2	**5.8**	**17.9**

SL: single layer ML: multilayer SLML: single and multilayer

- When and where can we “trust” the MCF algorithm?

Ideal multilayer case

- Only **daytime** footprints, MCF uses VIS to initiate the multilayer detection.
- Only **two cloud layers overlapped** based on MCF.
  - Footprints where CALIPSO-CloudSat mask only detects two layers.
- Upper layer CTH>=5km (~500 hPa).
- Lower layer CTH<5km.

Number of matched footprints by cloud overlap case
Daytime

MCF / CLCS	January	April	July	October
SL / SL	100217	80377	91682	95339
SL / ML	22222	34058	24141	30677
SL / SLML	122051	155660	142903	143177
SL / clear	6430	5494	5608	9528
ML / SL	2060	738	942	972
ML / ML	3399	3073	3168	2987
ML / SLML	6304	3605	4588	4324
ML / clear	0	0	0	0
SLML / SL	5915	4007	4382	4597
SLML / ML	10472	12179	14134	11483
SLML / SLML	25625	24788	32713	26480
SLML / clear	1	3	70	3
Clear / SL	23239	29100	25846	26245
Clear / ML	5782	7017	8069	5840
Clear / SLML	16925	21637	21766	15889
Clear / Clear	49463	19412	20363	25454
Total	**400105**	**401148**	**400375**	**402995**

SL: single layer ML: multilayer SLML: single and multilayer

Frequency of cloud overlap occurrence over matched footprints
Daytime

MCF / CLCS	January	April	July	October	Mean	
SL / SL	12.5	10.0	11.4	11.8	**11.4**	
SL / ML	2.8	4.2	3.0	3.8	**3.5**	
SL / SLML	15.2	19.8	17.8	17.8	**17.7**	**Total single**
SL / clear	0.8	0.7	0.7	1.2	**0.9**	**33.4**
ML / SL	0.3	0.1	0.1	0.1	**0.2**	
ML / ML	0.4	0.4	0.4	0.4	**0.4**	
ML / SLML	0.8	0.5	0.6	0.5	**0.6**	**Total multilayer**
ML / clear	0.0	0.0	0.0	0.0	**0.0**	**1.2**
SLML / SL	0.7	0.5	0.6	0.6	**0.6**	
SLML / ML	1.3	1.5	1.8	1.4	**1.5**	
SLML / SLML	3.2	3.1	4.1	3.3	**3.4**	**Total single-multilayer**
SLML / clear	0.0	0.0	0.0	0.0	**0.0**	**5.3**
Clear / SL	3.0	3.6	3.2	3.3	**3.3**	
Clear / ML	0.7	0.9	1.0	0.7	**0.8**	
Clear / SLML	2.1	2.7	2.7	2.0	**2.4**	**Total clear**
Clear / Clear	6.8	2.4	2.5	3.2	**3.7**	**10.2**

SL: single layer ML: multilayer SLML: single and multilayer

Number of matched footprints with only multilayer clouds on CLCS track
Daytime

CLCS footprints CLCS layers	January	April	July	October
2	4113	4153	3817	4120
3	15919	20889	17817	18613
4	12563	18702	16103	16209
5	5102	8043	7417	7311
6	1982	2851	2853	2843

MCF footprints CLCS layers	January	April	July	October
2	1090	956	1142	915
3	6502	6464	7772	6115
4	6112	7235	8708	6735
5	3083	3994	4693	3731
6	1409	1796	2045	1766

Total	801526	803669	803531	811242

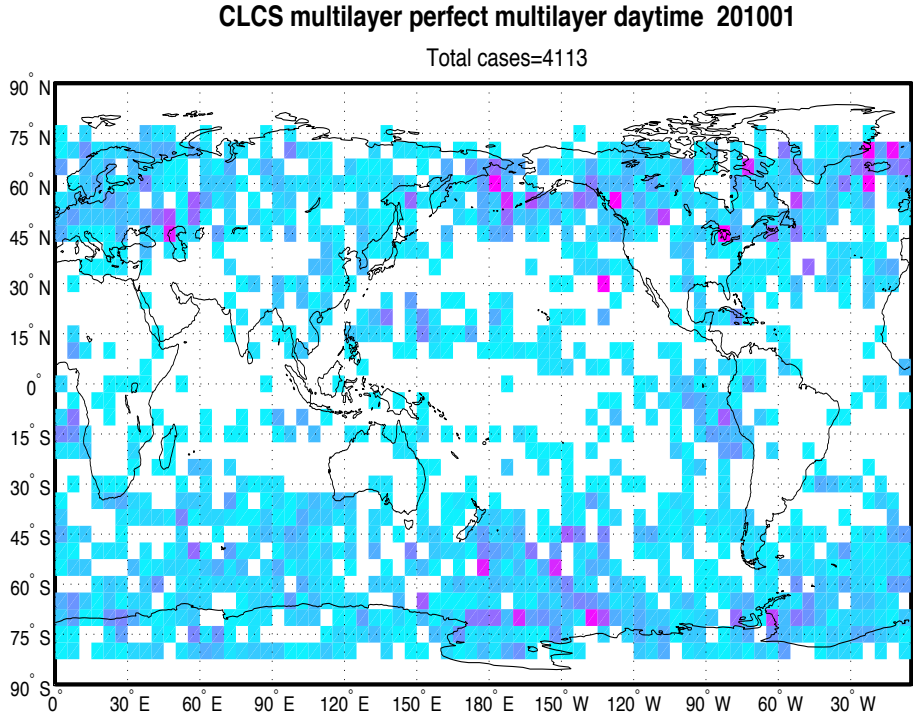
Frequency of cloud overlap occurrence
with only multilayer clouds over CALIPSO-CloudSat track
Daytime

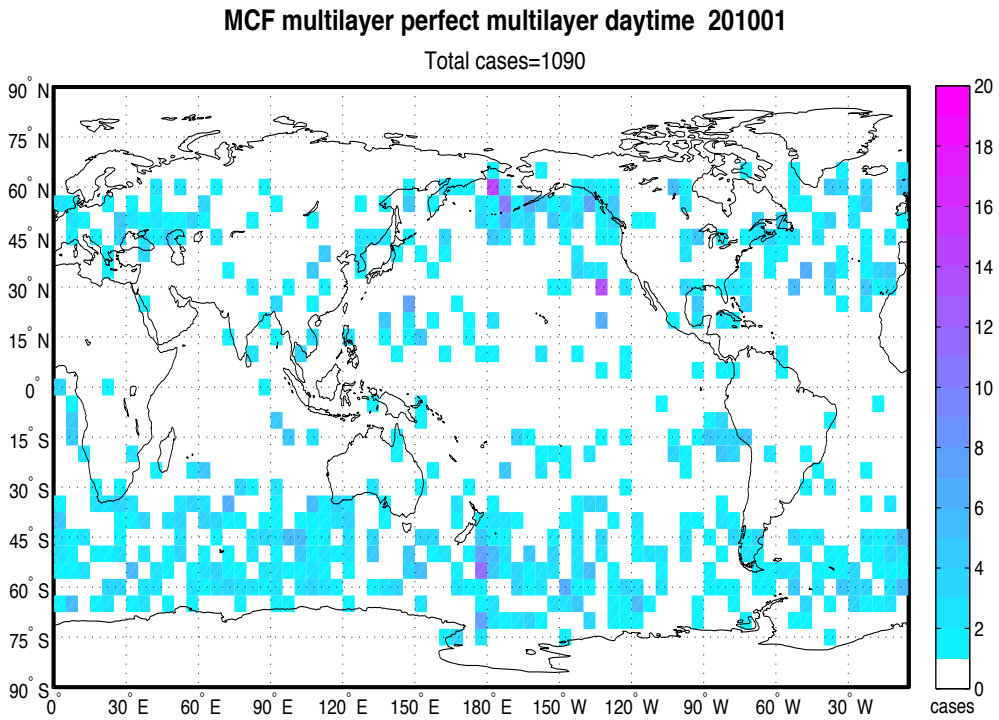
CLCS footprints CLCS layers	January	April	July	October
2	0.5	0.5	0.5	0.5
3	2.0	2.6	2.2	2.3
4	1.6	2.3	2.0	2.0
5	0.6	1.0	0.9	0.9
6	0.2	0.4	0.4	0.4

MCF footprints CLCS layers	January	April	July	October
2	0.1	0.1	0.1	0.1
3	0.8	0.8	1.0	0.8
4	0.8	0.9	1.1	0.8
5	0.4	0.5	0.6	0.5
6	0.2	0.2	0.3	0.2

Total footprints	801526	803669	803531	811242

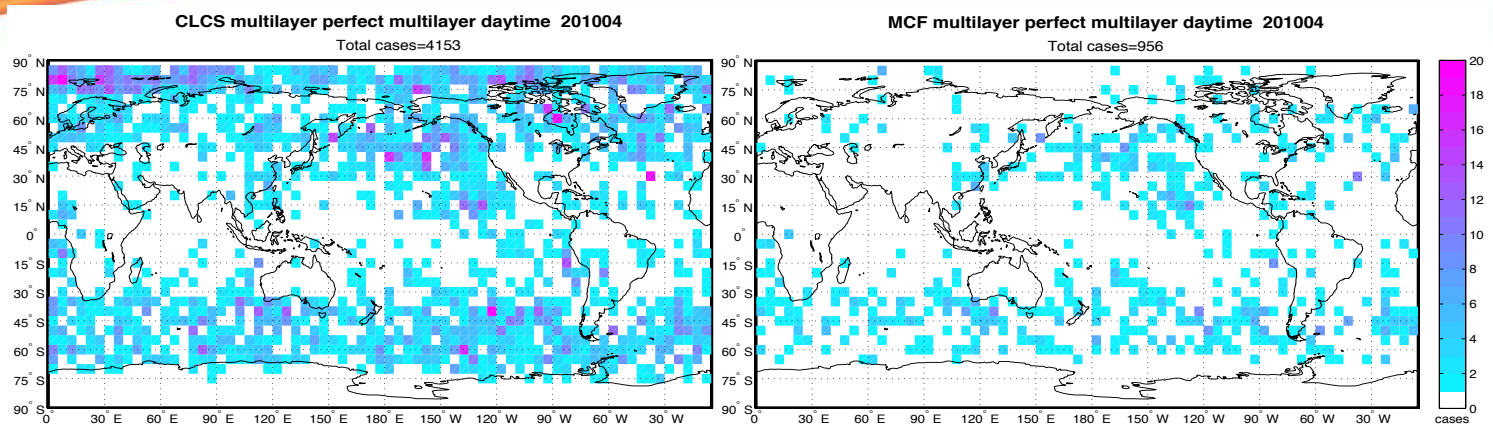
Global distribution of ideal multilayer case
All data and daytime



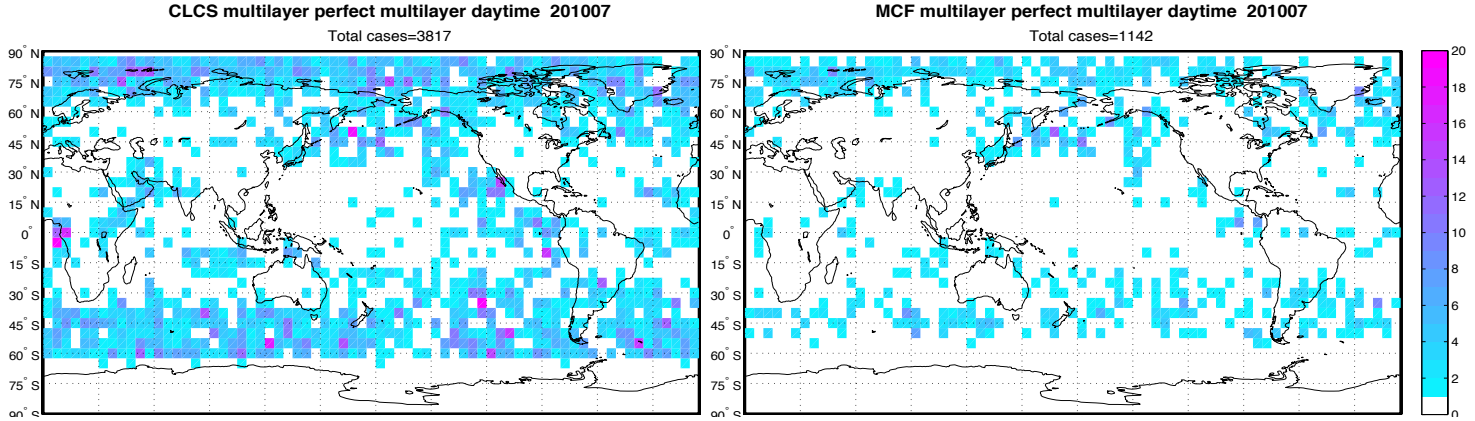


MCF algorithm only a 26% of all the multilayer cases from an "ideal multilayer" from CALIPSO-CloudSat.

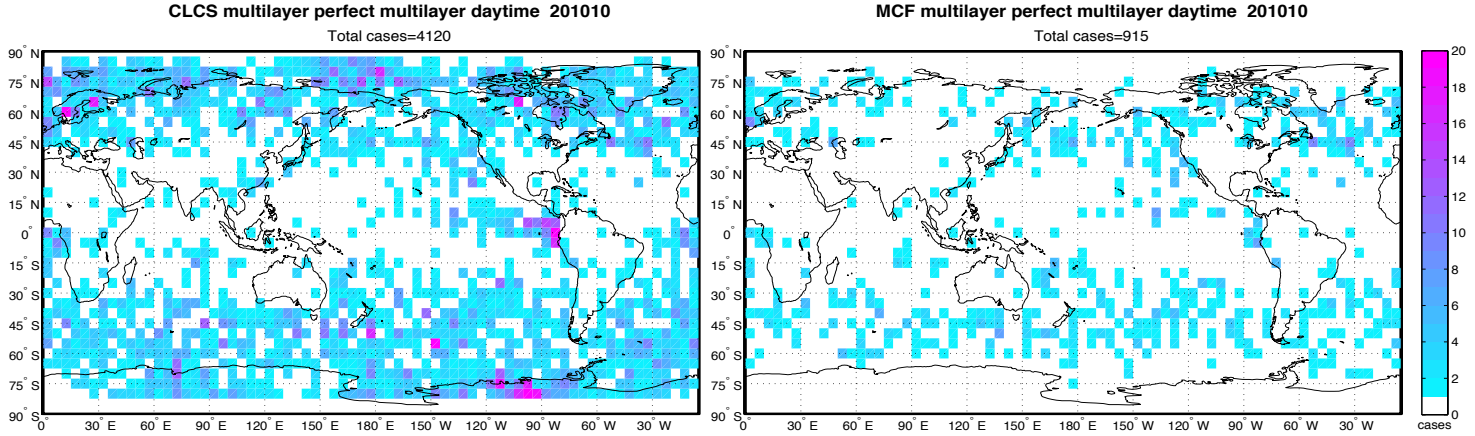
Global distribution of ideal multilayer case daytime



23%

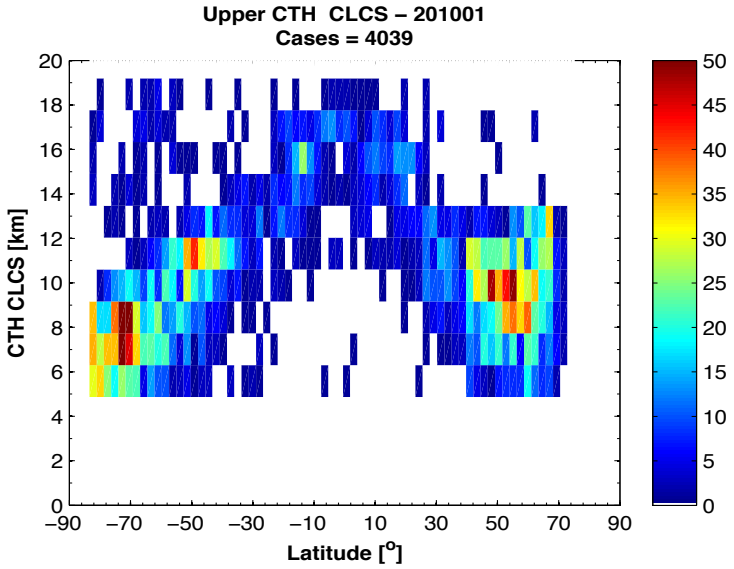


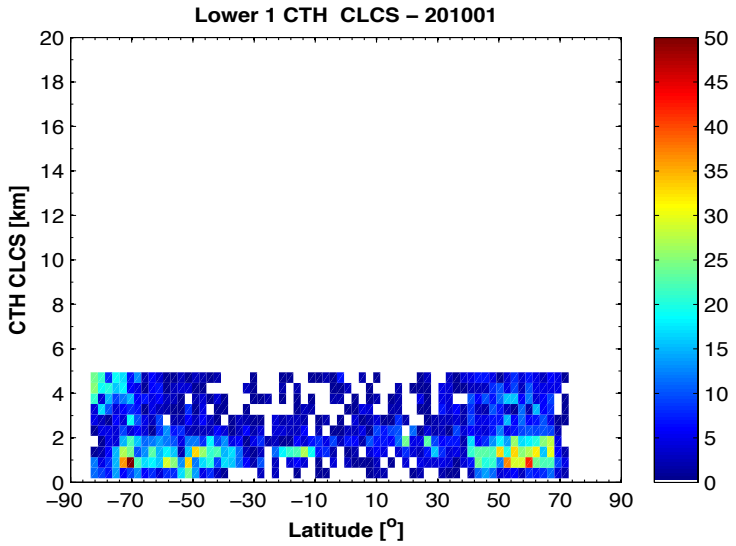
30%

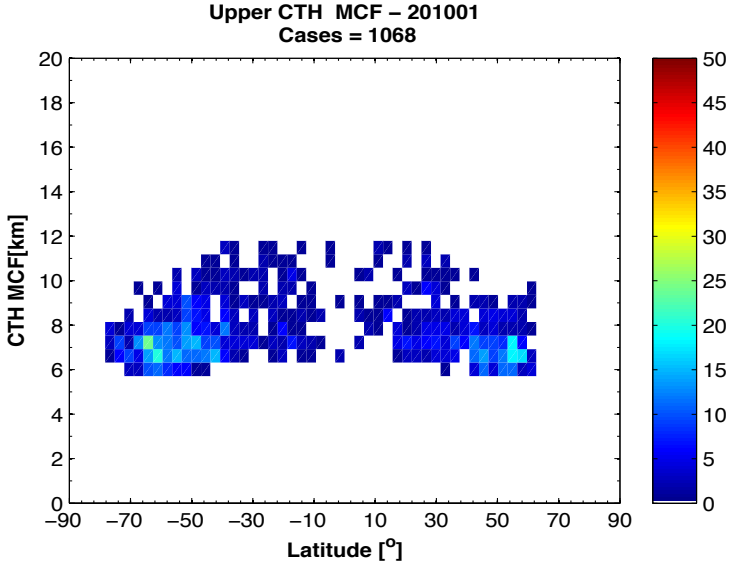


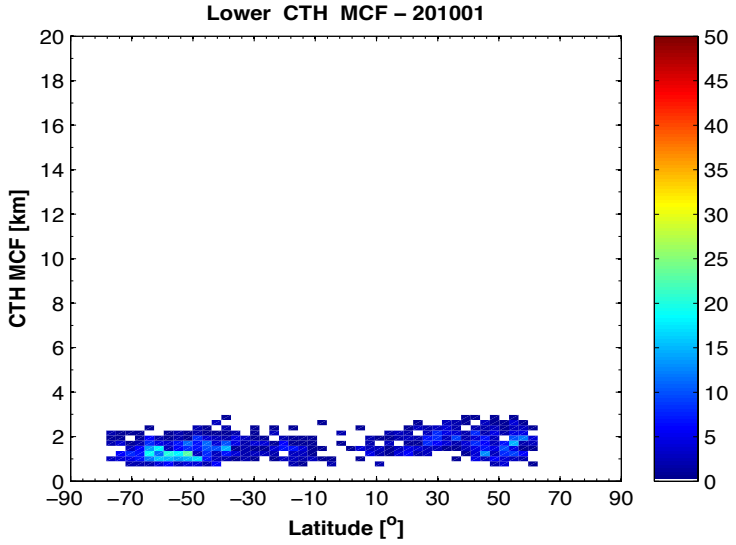
22%

CTH ideal multilayer case for CLCS and MCF daytime

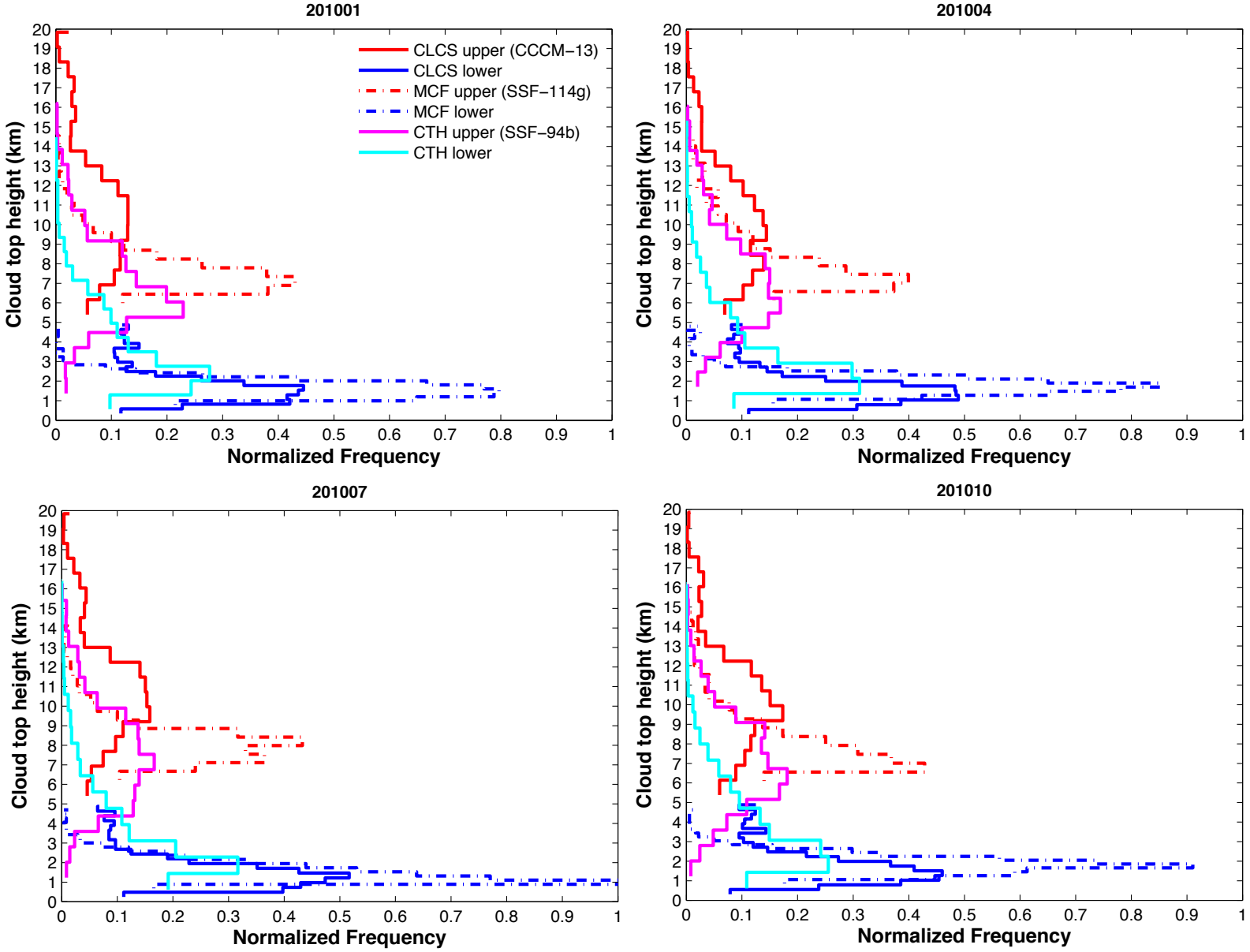




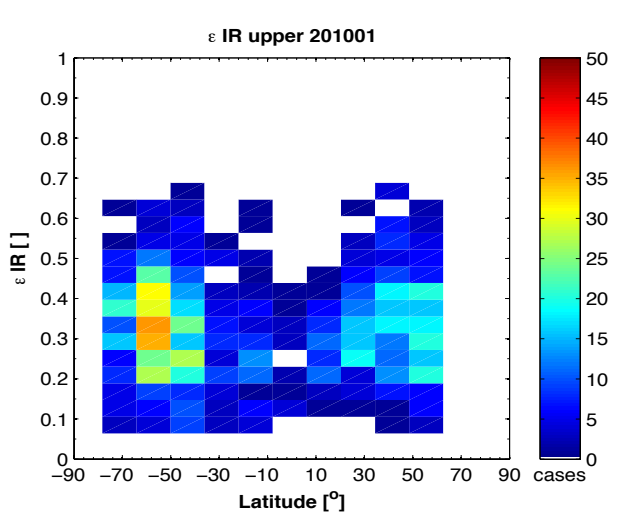


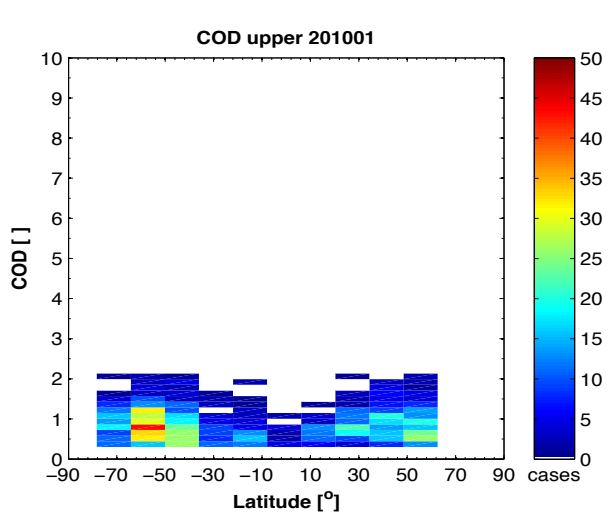


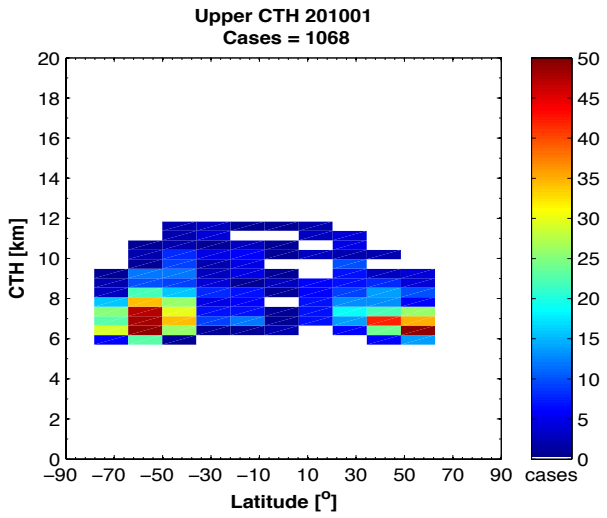
CTH vertical distribution for ideal multilayer case. CLCS and MCF matched footprints during daytime

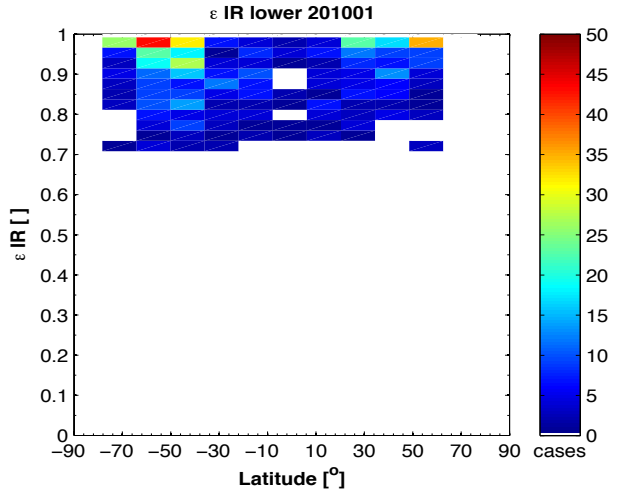


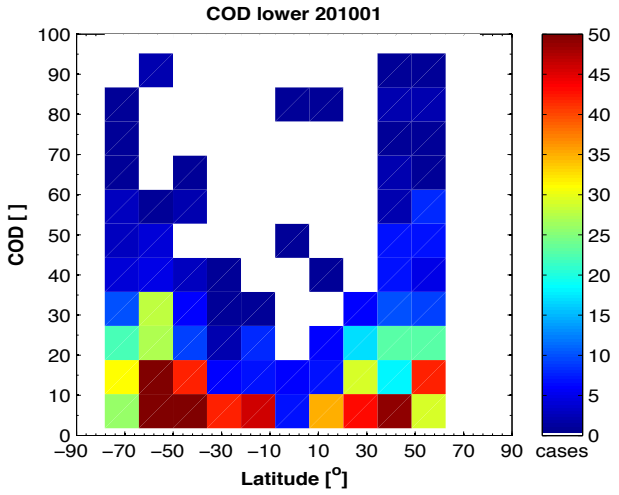
Emissivity, VCOD and CTH for ideal multilayer cases for MCF

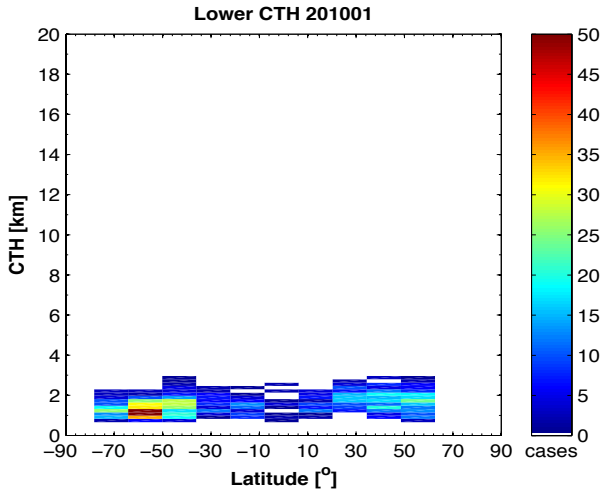












MCF only retrieves high clouds with $\varepsilon<0.8$ and $0.3<\tau_{VIS}3$

Conclusions and discussion

- MCF **underestimates** the multilayer cloud coverage in about 22% of all the cases analyzed.
- The MCF algorithm **overestimates** the presence of single clouds ~10% over the multilayer compared to CALIPSO-CloudSat.
- The MCF **underestimates** the total amount of clouds for the data available evaluated in about 15%.
- For all the matched footprints evaluated between MCF~CLCS: ~74% are SL, ~1% ML, ~7% SLML and ~18% clear. MCF miss value ~10% of ML from CLCS.
- For an ideal case of two multilayered clouds over a whole CERES footprint, MCF is strongly limited to areas where CLCS detects most of the multilayer clouds.
- The only case that MCF agrees better with CLCS is when footprints are during daytime and the $\varepsilon_{hc}<0.8$.


Thanks for your attention.